INVESTIGATION OF NEW SIDE IMPACT TEST PROCEDURES IN JAPAN

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ABSTRACT

In recent years there has been a strong shift away from traditional sedans to multipurpose vehicles, such as vans and minivans. This trend is centered in North America, but has also become conspicuous in Japan and Europe.

Considering the current situation, including the issue mentioned above, a review of the test procedures in the current regulations has become a matter of some urgency. Based on a common awareness in Japan, Europe, and America, the IHRA is actively promoting research on side impact test procedures. Research is also moving forward on important issues including types of crash dummies and their positions in the vehicle. In order to take an active part in the research promoted by the IHRA, Japan is also conducting investigations into these issues. Japanese studies have included surveys of specifications for vehicles on the market in recent years, investigations of the front-end stiffness of these vehicles, analyses of traffic accidents, and other studies, especially analyses of collision effects that lead to injuries. To do this, full-scale side impact tests have been conducted under various conditions, and factors affecting the vehicle deformation and dummy responses have been examined. These results were reported in part at the 17th ESV Conference held in Amsterdam 2001.

This report describes full-scale side impact tests in which a multipurpose vehicle, which has a different front shape and stiffness than conventional sedan-type cars, is the striking vehicle. The amount of deformation of the vehicle body and dummy responses were compared and adjusted in terms of results with the present test procedures. Tests were also conducted with rear seat dummies (SID-IIs), and suggestions for the test conditions in future side impact test procedures are made from a wide range of viewpoints.

INTRODUCTION

Vehicle side impact standards in Japan were introduced on a par with the ECE/R95, but in actual traffic conditions in Japan, the number of persons injured by side impact accidents has consistently increased, so that accident conditions related to vehicle side impacts are as significant as ever. Especially in the case of accidents involving the recently popular sport utility vehicles (SUVs), minivans, and 1box vehicles with a high frame side impacting normal passenger cars, there is a marked tendency for severe damage to the passenger car.

In this study, vehicle side impact tests were performed using bonnet-type compact passenger cars as the struck vehicle, and an SUV, minivan, 1box, and IIHS MDB as the striking vehicle. Results of vehicle and crash dummy tests under current regulations (ECE/R95) are compared below.

TEST CONDITIONS OF FULL-SCALE SIDE IMPACT TEST

Impact configuration

Table 1 shows the impact configurations and test conditions. The four tests were conducted using an SUV, minivan and 1box as the striking vehicle (nos. 1-3), and IIHS MDB as the striking vehicle (no. 4). Also shown in the drawing is the ECE/R95 impact configuration for the purpose of comparison with the four test results (no. 5 reference).

The four tests were performed under substantially the same conditions, with the exception that different vehicles were used as the striking vehicle. Right angle side impact was produced on the struck vehicle at a speed of 50 km/h without any crab angle. The position of the striking vehicle relative to the struck vehicle was arranged to have the control center of the striking vehicle match the front seat reference point (SRP) of the struck vehicle, as prescribed for side impact tests in Europe and Japan.

Vehicles and Dummies

Struck Vehicles - Four-door sedan-type passenger cars without side airbags were used as the struck vehicles. The vehicle had average specifications for a Japanese passenger car, and has been used in a past series of side impact tests. This vehicle was selected on the basis of future data comparisons.

Striking Vehicles - The SUV was selected from among models which have had relatively high unit sales in recent years, and was of average size for a Japanese SUV relative to empty mass. This vehicle mass is 1340 kg, near the 50 percentile mass value of 1355 kg for SUVs sold in Japan in 1998. The minivan and 1box models used in Japan have very large differences in front-end configurations, and were selected from among models close to the SUV in mass.

The IIHS MDB is a barrier face attached to a moving barrier, and was developed by the IIHS in the United States, for use in side impact safety evaluation tests involving the head, and is said to imitate the shape and dimensions of the front-end of an SUV.

Mass of Test Vehicles - Table 2 shows the mass distributions of the striking vehicle and struck vehicle for each test. The selected struck vehicles were the same models used in a past series of side impact tests. Mass of struck vehicles was 1432 kg. The striking vehicles, i.e., SUV, minivan, 1box and IIHS MDB were all set at 1500 kg. This mass setting was intended to simulate the 50 percentile of two adult male passengers (150 kg) added to the 50 percentile mass (1355 kg) of a Japanese SUV. This was decided in the light of the IIHS MDB mass (1500 kg) used in tests reported for the IHRA side impact WG.

Relationship of Test Vehicle Height and Position - Figure 1 shows a comparison of the average dimensions of Japanese vehicles and the current barrier face configuration with the height dimensions of the SUV, minivan, 1box and IIHS MDB. The average values for Japanese vehicles shown in this drawing are weighted averages derived from the dimensions of sedans, minivans, and SUVs sold in Japan in 1998 weighted by the number of units sold.

As shown in the figure, the bottom edge height of the SUV front side member is 395 mm, which is approximately 20 mm higher than the 376 mm

Table 1. Test conditions in full-scale side impact test

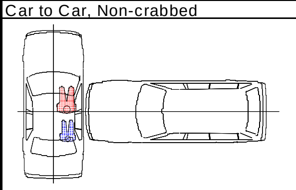
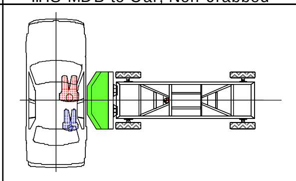
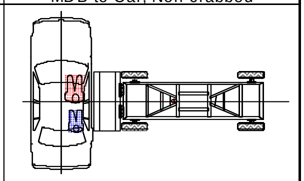
Test No.	1-3	4	5 (Refrence)
	Car to Car, Non-crabbed	IIHS MDB to Car, Non-crabbed	MDB to Car, Non-crabbed
Impact Configuration			
Impact Velocity	50km/h	50km/h	50km/h
Striking Vehicle Type	SUV, Minivan, 1box	MDB (IIHS type Barrier face)	MDB (ECE/R95 type Barrier face)
Striking Vehicle Mass	1500kg	1500kg	950kg
Struck Vehicle Type	Passenger Car (4drSD)	←	←
Struck Vehicle Mass	1432kg	←	←
Front Struck side Dummy	EUROSID-1	←	←
Rear Struck side Dummy	SID-IIs	←	←

Table 2. Mass distribution of test vehicle

Test No.		1			2			3			4			5 (Refrence)		
Test		SUV			Minivan			1box			IIHS MDB			R95 MDB		
		Left	Right	Total	Left	Right	Total	Left	Right	Total	Left	Right	Total	Left	Right	Total
Struck Vehicle	Front Axle	393	421	814	392	428	820	393	428	821	394	425	819	393	433	826
	Rear Axle	291	327	618	287	325	612	286	325	611	290	323	613	283	323	606
	Total	684	748	1,432	679	753	1,432	679	753	1,432	684	748	1,432	676	756	1,432
Striking Vehicle or MDB	Front Axle	402	418	820	418	435	853	458	458	916	415	526	941	333	304	637
	Rear Axle	342	338	680	324	323	647	290	294	584	346	213	559	140	171	311
	Total	744	756	1,500	742	758	1,500	748	752	1,500	761	739	1,500	473	475	948

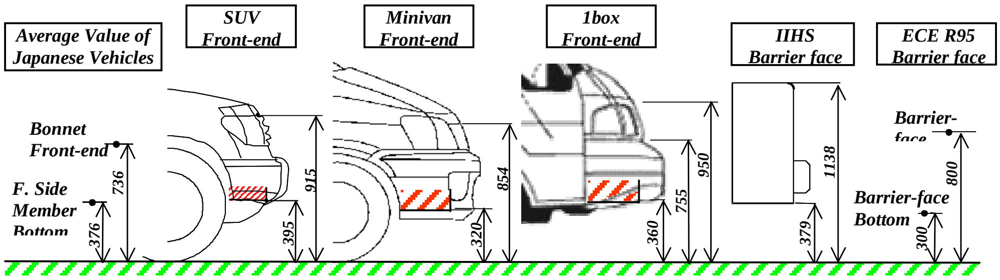


Figure 1. Relationship of test vehicle height, MDB height and average height of Japanese vehicles

weighted average of Japanese cars, and the hood front edge height of 915 mm is about 180 mm higher than the 736 mm weighted average of Japanese cars. The bottom edge height of the minivan front side member is 360 mm, which is lower than the average for Japanese cars, the hood front edge height of 854 mm is about 120 mm higher than the average for Japanese cars. The bottom edge height of the 1box front side member is 320 mm, which is the same as the average of Japanese cars. The height of the bottom line of the front panel of the 1box is 755 mm, and the height of the press line of front panel of the 1box is 950 mm. Although the bottom edge height of the IIHS MDB barrier face, at 379 mm, is about the same as the weighted average for Japanese vehicles, the top edge height, at 1138 mm, is approximately 400 mm higher than the weighted average of the hood top edge height of Japanese cars. The top edge of the IIHS MDB barrier face matches the intermediate height from the windowsill to the roof side rail of the struck vehicle.

Dummy and Setting Position - In this test, an adult-size male dummy (EUROSID-1), used in current European and Japanese side impact test procedures for driver-side front seat impact, was used, as was a smaller female AF5 percentile passenger rear seat side impact dummy (SID-IIs). Both dummies were secured using 3-point seat belts, which were standard-equipped in the struck vehicle. The front seat was set at an intermediate position of the seat adjustment slide rail, the seat back was set at the design standard position with the headrest position at the maximum height, and the steering wheel tilt mechanism in an intermediate position within the adjustment range. The seat slide and seat back of the passenger seat on the side opposite the impact were set the same as the driver's seat.

For reference, Figure 2 shows the dummies seated in the struck vehicle.

Figure 2. Dummies in struck vehicle

Measurement Items - In this test, the dummy was equipped with instrumentation for measuring acceleration, load, and displacement. And acceleration of the vehicle, and acceleration near the center point of the MDB were measured. These parameters were measured by an in-vehicle measurement device. Measurement data were processed according to SAEJ211 in accordance with the measurement content. The profile of the outside panel on the impact side of the struck vehicle, and the front of the striking vehicle and front of the barrier face were measured before and after the test. The test vehicles and the dummies were photographed using a high-speed video camera.

TEST RESULTS

Vehicle and Barrier Face Deformations

Figure 3 shows the condition of the striking vehicle and struck vehicle immediately after impact, Figure 4 indicates the deformation of the impact vehicle after the test, and Figure 5 indicates the deformation of the striking vehicle exterior. The deformation of a horizontal cross section of the struck vehicle prepared from measurement results is shown in Figure 6, while the deformation of a horizontal cross section of the barrier face is seen in Figure 7.

Compared to the regulation test (ECE/R95 MDB test), the deformation in these four tests was severe. The smallest deformation occurred on the front seat reference point (SRP) at the hip-point (H.P.) level of the minivan, with the other three tests showing similar deformation tendencies more severe than for the minivan. Compared to the regulation test, deformation of the front door position at the H.P. level was markedly severe in all four tests. The IIHS MDB test showed overall nearly uniform deformation, whereas the 1box, minivan and SUV tests tended to result in severe deformation near the center of the front and rear doors. The IIHS MDB test produced the largest deformation at the HP level near the seated position of the rear seat dummy (3 m from the front edge of the vehicle), and the deformation at the thorax level was greater than that of the regulation test, excluding the minivan.

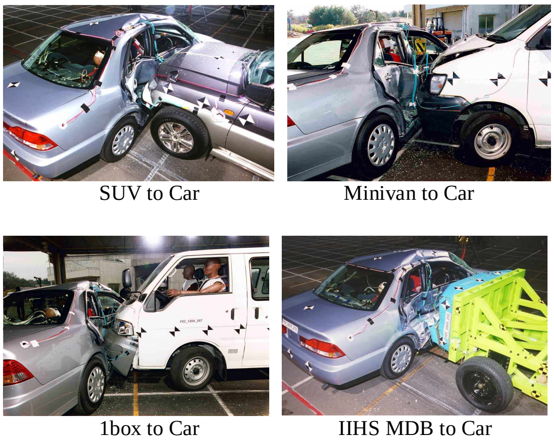


Figure 3. Striking vehicle and struck vehicle at the impact

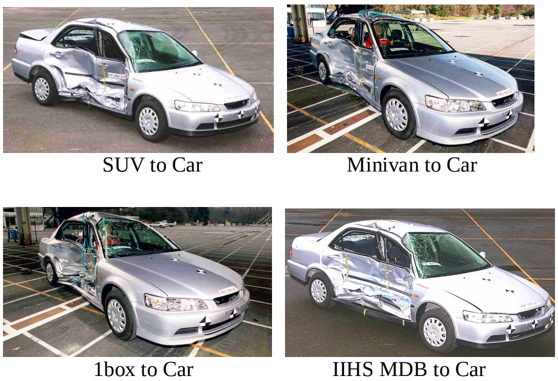


Figure 4. Struck vehicle exterior: after test

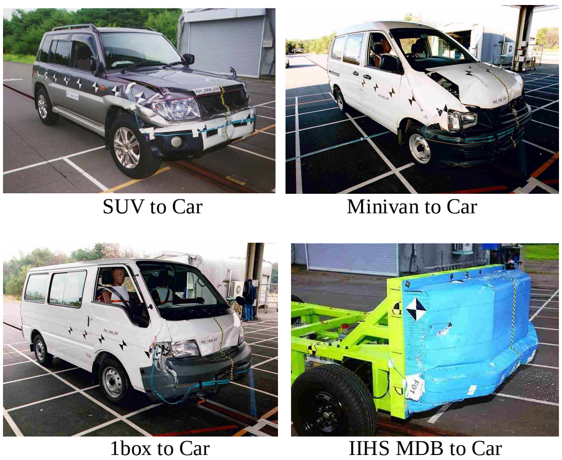


Figure 5. Striking vehicle exterior: after test

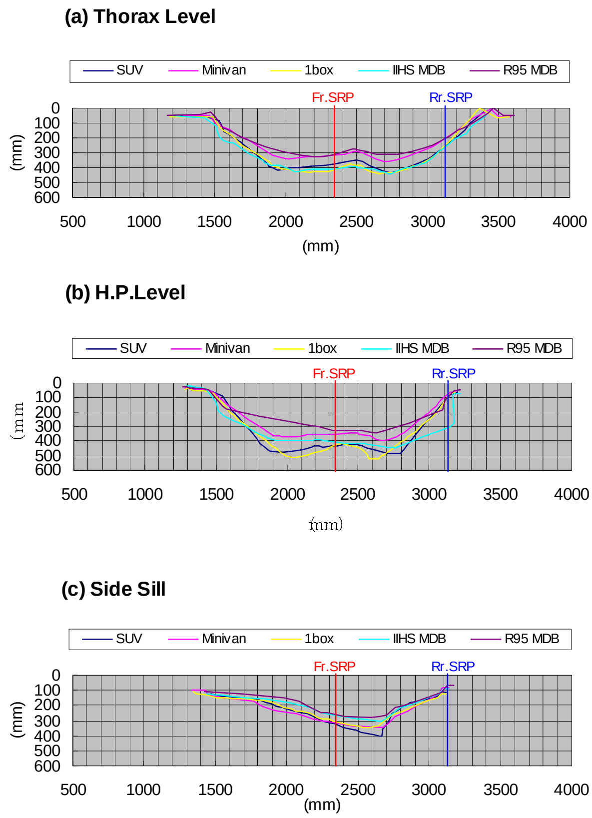


Figure 6. Deformation of horizontal cross section of struck vehicle

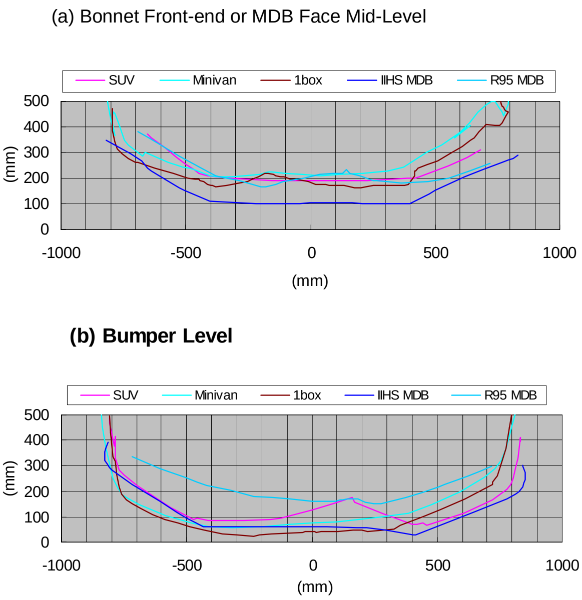


Figure 7. Deformation of horizontal cross section of striking vehicle

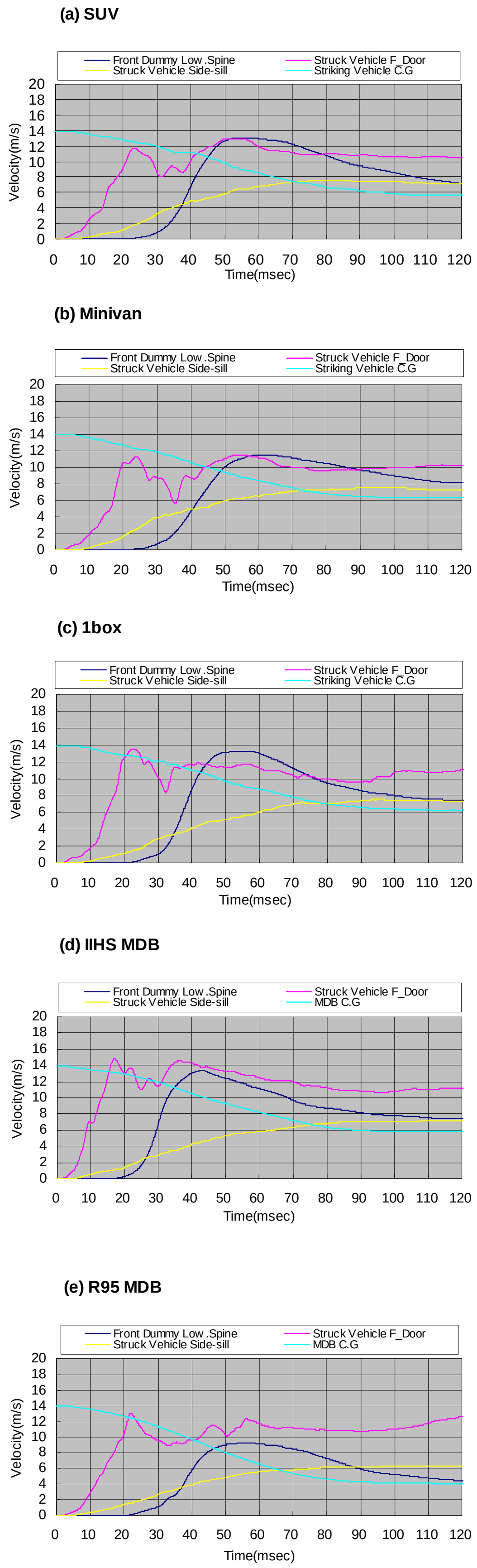


Figure 8. Velocity time history of test vehicle and dummy

These deformations differ greatly from the regulation tests, conceivably owing to the large influence on the dummy responses.

Except for the IIHS MDB test, the form of the deformation by the striking vehicle was similar in mode to that of the regulation test at mid-level and front SRP. In the IIHS MDB test, however, there was little deformation due to the barrier rigidity. The amount of deformation at the bumper level was slight in the present four tests compared to the regulation test. The amount of deformation was particularly slight in the 1box test, which is likely due to the rigidity of the front section.

Velocity Time History of Test Vehicle, MDB and Dummy

Figure 8 compares the regulation test and the present four tests relative to the velocity time history of the various parts by integrating the acceleration data obtained for the test vehicles, MDB and front seat dummy. In the struck vehicle, there was lateral acceleration near the center of the front door and side sill on the side opposite the impact, and the front seat dummy experienced lateral acceleration at the T12 lower spine. There was also acceleration in the longitudinal directions at the center of gravity of the striking vehicle. The trade-off point between the striking vehicle and the MDB in the regulation test was about 65 ms from the moment of generation, and the velocity at that time was 5.8 m/s. In contrast, in the present four tests, the trade-off point was about 70 - 80 ms from the moment of generation, and the velocity at that time was 6.8 - 7.3 m/s.

The velocity change inside the door wall in the regulation test was 13 m/s at maximum, and the velocity at the moment of generation was 23 ms. In the present four tests, the values were lowest at 11 m/s (24 ms) for the minivan, and highest at 15 m/s (17 ms) for the IIHS barrier test.

In the regulation test, the velocity change at the lower spine of the dummy attained a maximum value of 9 m/s, and the value at the moment of generation was 50 ms. In the present four tests, the lowest value of 11 m/s (60 ms) occurred in the minivan, and the highest of 13.3 m/s (44 ms) in the IIHS MDB test, similar to the door inner wall.

The dummy velocity change was demonstrated to be greatly affected by variation in the velocity of the door inner wall.

Response of Dummies

Table 3 indicates response of various parts of the front seat and rear seat dummy. In the table, the pubic force on the front seat dummy in the SUV and 1box generated two peaks in the force-time graph. These two items were adjusted using the maximum value before the second peak.

Table 3 (a). Front dummy peak responses

Test No.	1	2	3	4	5
Test	SUV	Minivan	1box	IIHS MDB	R95 MDB
HPC	480	398	300	2634	194
Thorax U.Rib Defl.	39.0	39.8	43.2	44.5	39.4
Thorax M.Rib Defl.	34.6	32.8	38.8	45.7	33.8
Thorax L.Rib Defl.	32.0	25.6	36.4	50.2	31.5
Thorax U.Rib V*C	0.680	0.491	0.915	1.060	0.672
Thorax M.Rib V*C	0.770	0.354	0.914	1.280	0.664
Thorax L.Rib V*C	0.710	0.313	0.889	1.520	0.593
Abdominal Force	2.06	1.19	2.14	1.65	1.62
Pubic Force	5.06	3.34	5.63	5.62	3.68

Table 3 (b). Rear dummy peak responses

Test No.	1	2	3	4	5
Test	SUV	Minivan	1box	IIHS MDB	R95 MDB
HPC	406	582	544	547	300
Shoulder Rib Defl.	20.6	30.1	29.2	21.9	14.3
Thorax U.Rib Defl.	17.6	22.0	23.8	15.0	15.2
Thorax M.Rib Defl.	12.5	17.8	19.8	12.8	13.8
Thorax L.Rib Defl.	8.0	15.4	13.1	16.0	16.0
Abdominal U.Rib Defl.	6.9	16.0	7.7	15.6	15.1
Abdominal L.Rib Defl.	4.9	9.4	5.9	12.0	9.6
Pubic Force	0.75	0.61	0.60	0.66	0.42
Iliac Force	0.04	0.08	0.15	0.40	0.05
Acetabulum Force	1.34	1.52	1.96	2.11	1.07

Front Seat Dummy - A comparison of the response of each part of the front seat dummy in the regulation test and the preset four tests is shown in Figure 9. The head acceleration, thorax lower rib displacement, thorax lower rib V*C, and pubic force-time graph are shown in Figure 10 as examples of response.

HPC is 194 in the regulation test. In the present four tests, the values ranged between 300 - 480, except for the IIHS MDB, for which the value was 2634. This high value is a phenomenon generated by direct impact of the dummy head on the top of the barrier face during impact. In the regulation test, thorax deflection and V*C were 39.4 mm and 0.672 m/s, respectively. Values in the SUV and minivan tests were near those in the regulation test. In the 1box and IIHS MDB tests, thorax deflection was 43.2 - 50.2 mm, and V*C was 0.915 - 1.52 m/s, the highest values. Excluding the IIHS MDB, the upper rib values were larger than those of thorax deflection and V*C.

Conversely, the IIHS MDB test had the largest value for the lower rib, which is thought to be due to the large influence of the IIHS barrier bumper shape and stiffness. The abdominal force in the regulation test was 1.62 kN. This value was lowest in the minivan test, at 1.19 kN, and largest in the 1box test, at 2.14 kN. Pubic force in the regulation test was 3.68 kN. This value was lowest in the minivan test, at 3.34 kN, and largest in the 1box and IIHS MDB tests, at 5.62 kN. Regarding front seat dummy responses, test results revealed more severe damage in the regulation test and minivan and SUV tests than in the 1box test using the IIHS barrier.

The present four tests differed greatly in front face configuration and rigidity with regard to the barrier characteristics of the regulation test. Accordingly, there were large differences in the mode of deformation of the struck vehicle, particularly the shape of the deformation at the dummy seating position, which produced differences in the injuries of each part of the dummy. When considering the performance of the MDB, which is intended to represent the market, it seems, based on investigation of test results using various types of vehicles, that vehicles recently appearing on the market have greater impact resistance.

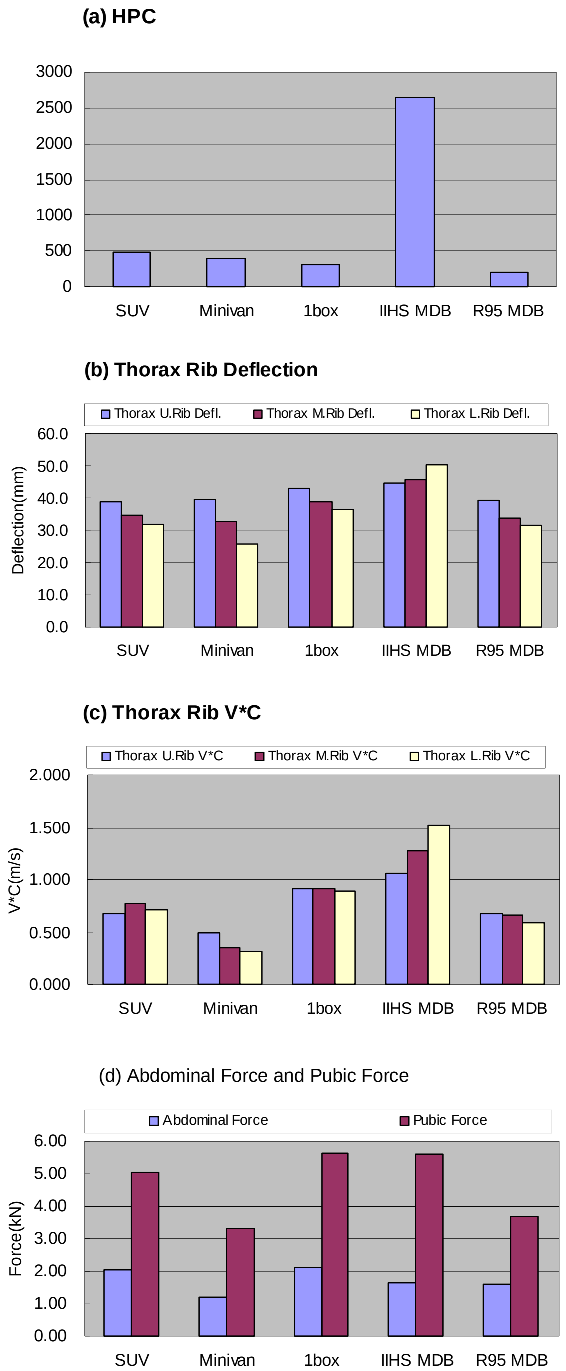


Figure 9. Comparison of front dummy responses

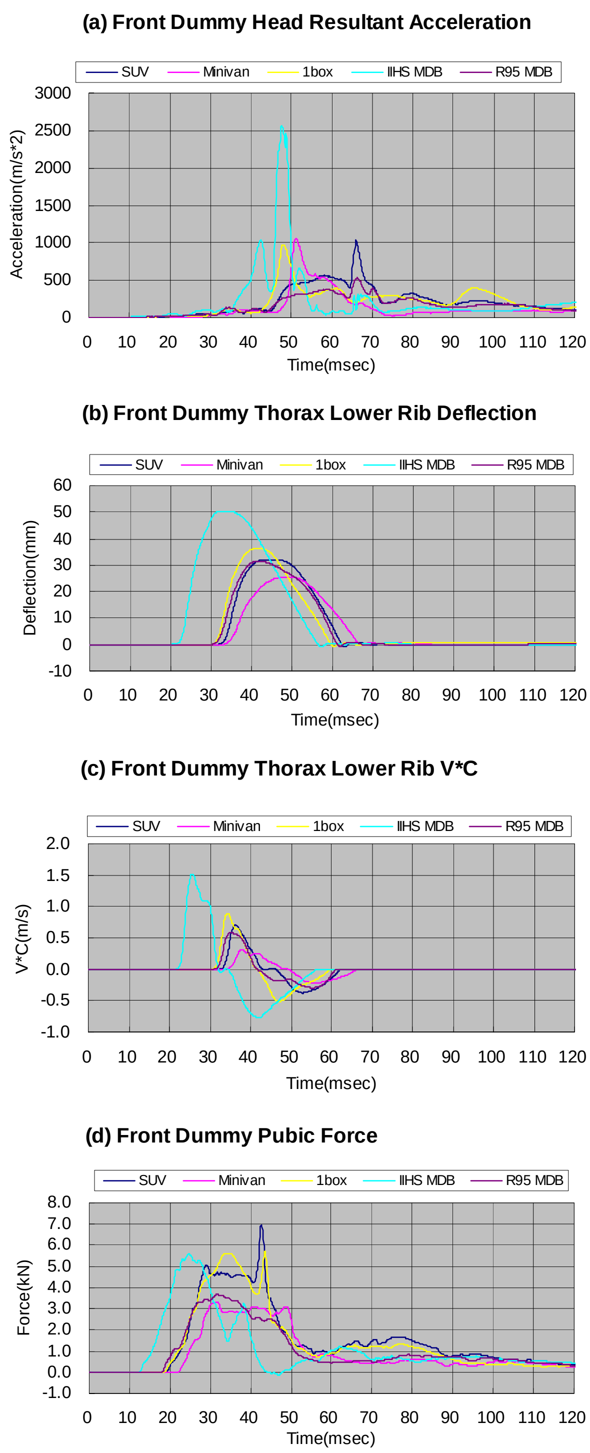


Figure 10. Time history of front dummy responses

Rear Seat Dummy - The response of each part of the rear seat dummy is compared for the regulation test and the present four tests in Figure 11. The head acceleration, thorax lower rib deflection, thorax lower rib V*C, and pubic force-time graph are shown in Figure 12 as examples of response. HPC was 300 in the regulation test. Values were invariably large in the present four tests, with the SUV having the smallest value at 406, and the 1box indicating the largest value at 582.

In the regulation test, thorax deflection was 16.0 mm. Values were generally large in the four present tests, with the smallest value of 17.6 mm occurring in the SUV test, and the largest value of 30.1 mm in the 1box test.

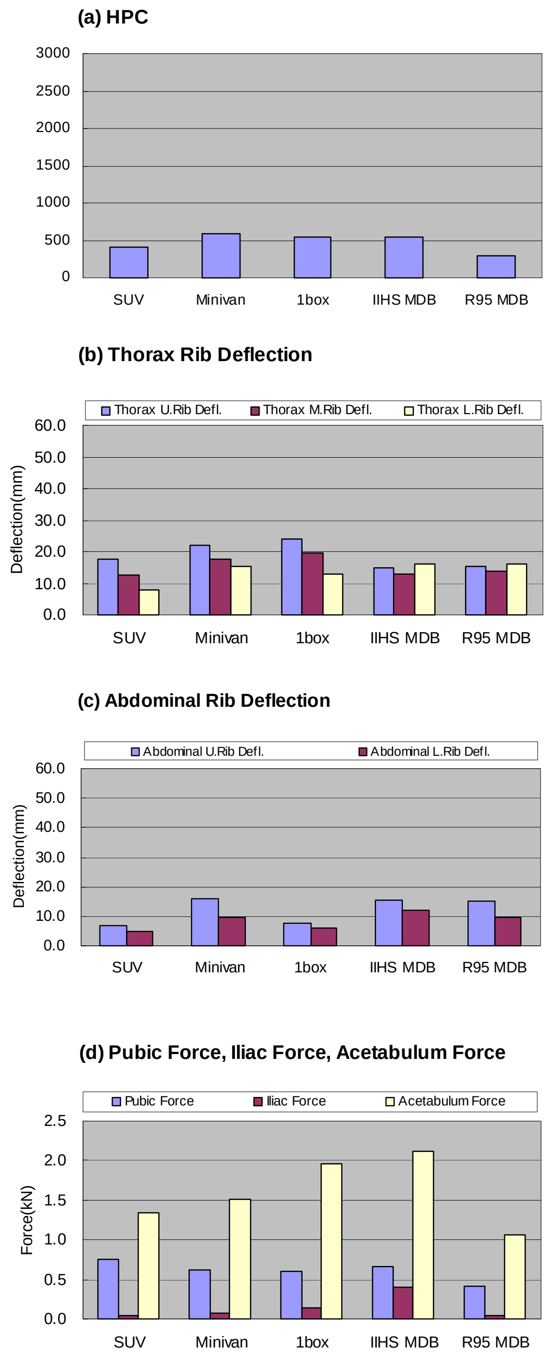


Figure 11. Comparison of rear dummy responses

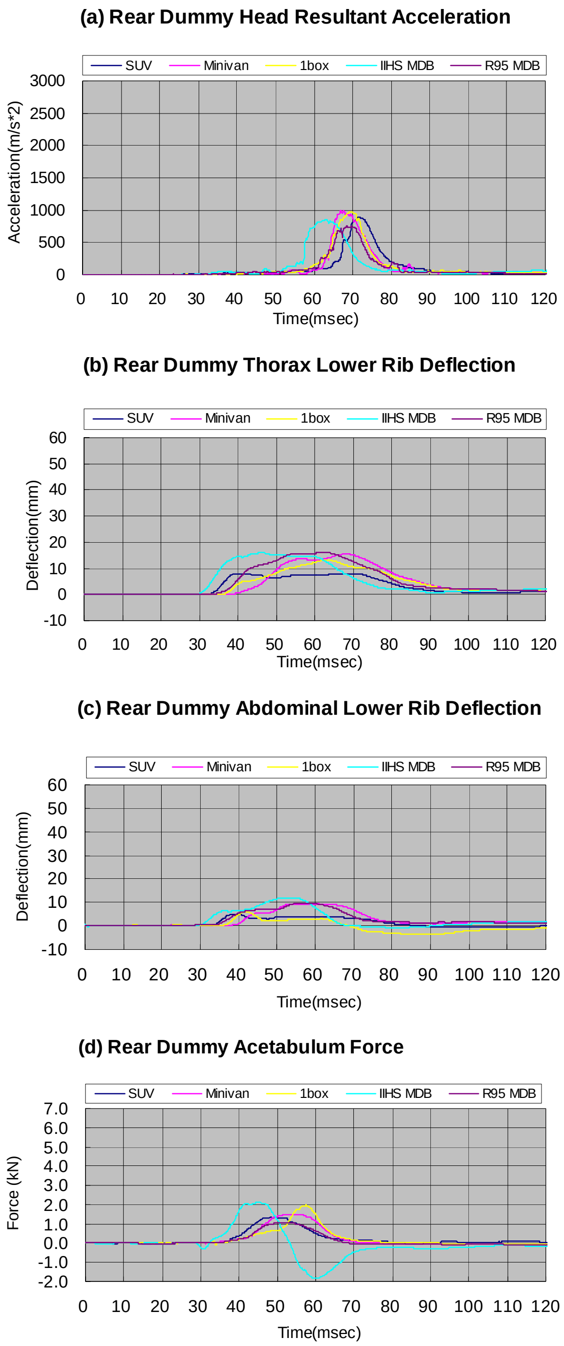


Figure 12. Time history of rear dummy responses

Abdominal deflection in the regulation test was 15.1 mm, but was even smaller in the SUV test at 6.9 mm. The maximum value of 16.0 mm occurred in the 1box test. Pubic force in the regulation test was 0.42 kN. The value was generally large in the four present tests, with the minivan test showing the smallest value at 0.61 kN, and the SUV test the largest at 0.75 kN.

The rear seat dummy was a SID-IIs model, and the responses of this dummy could not be compared directly with the front seat dummy. However, there were large differences in injury criteria such as HPC, thorax deflection and the like compared to the regulation test. In the regulation test, the rear seat dummy responses were minor compared to that of the front seat dummy, as determined from the barrier specifications, but in the SUV, minivan and 1box tests, there was severe vehicle deformation at the seating position of the rear seat dummy, indicating a high probability of severe damage.

The necessity of installing a rear seat dummy in setting the conditions for future regulation test is an important issue requiring more study.

CONCLUSIONS

The following conclusions have been drawn from a comparison of the regulation test with the results of our investigation into the effects on a struck vehicle and its occupants when the striking vehicle is an SUV, minivan and 1box, which have recently become increasingly popular.

1. The vehicle deformation, of course, differs greatly depending on the penetration speed at the door of the struck vehicle, and produces significant differences in the responses of the dummies.
2. In the IIHS barrier test, which was developed to have characteristics similar to an SUV, the deformation mode of the stuck vehicle is similar to an SUV, but there are considerable differences in the responses of dummies. These differences arise from the differences in local deformation (i.e., particularly the dummy seating position) of the struck vehicle. Specifically, the HPC in the IIHS MDB test clearly showed larger values than other tests regarding head impact directly with the barrier.
3. In the SUV, minivan and 1box tests, there are considerable differences in the deformation of the rear seat passenger seating positions, and severe dummy responses were sustained. The necessity of installing a rear seat dummy is an important issue requiring further study including the size of the dummy.
4. In the MDB test and actual vehicle test, there were differences in local deformation, which influences the responses at the various parts of the dummies. This aspect will require thorough study of the structure (i.e., homogeneous type or non-homogeneous type) of the MDB as specified by the conditions of the regulation test.

The test conditions of the current regulation were determined from the characteristics of the vehicles on the market in the 1970's. Vehicles available on the current market are more diversified and were developed in response to many safety regulations.

Following these developments, there is a need for further study into determining the conditions for a new regulation test based on the results of this investigation.

When considering the performance of the MDB, which is intended to represent the market, it would appear that an MDB could be provided which better represents the currently available impact-resistant vehicles in the market, based on investigation of the various vehicles used in the present four tests. In determining MDB performance, studies of compatibilities will be a very important area of future research.

Results of the present study will be reported at the IHRA Side Impact Working Group, and used as basic data when creating new regulations. In the meantime, fundamental research will be actively pursued.

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